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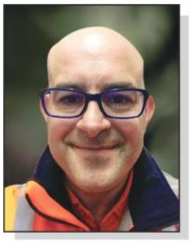
Strength, odour, and hygiene - in the face of increased re-use of fibre & water



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ABSTRACT

A significant problem facing the pulp and paper industry is anaerobic papermaking. Anaerobic papermaking suggests that the papermaking conditions favour facultative and anaerobic bacteria, which can thrive in the absence of oxygen. These conditions arise from making paper with less water and a decreasingquality of recycled fibre. These anaerobic conditions lead to; increased specialty chemical use, increased paperodour issues, decreased paper strength, and increased challenges associated with product hygiene (read: food safety).

Reducing the time that fluids remain in a vessel, helps to minimise anaerobic conditions. Focusing on key physico-chemical and electrochemical parameters (e.g. pH, oxidation-reduction potential (ORP), and temperature) can move papermaking systems towards aerobic conditions thus minimising the negative impacts of making paper under anaerobic conditions.

Keyword: *Mill closure, odour, recycling, strength aids, circular economy, lightweighting, biocides, food safety, contaminants, volatile fatty acids (VFAs), environmentalism, aerobic, and anaerobic.*

Introduction

Several challenges (read: trends) are being seen by modern papermakers. (1) A pressure to decrease cost, which leads to; lower quality recycled fibres, lighter weight paper (read: lightweighting), increased filler use (e.g. ground calcium carbonate GCC), decreased chemical use water use, and decreased waste disposal. (2) A pressure to decrease single use plastics, which leads to an increased demand for food contact (read: food safety) paper products. (3) Circular economy (read: reduce, re-use, recycle) pressures are forcing papermakers to make paper; with less fresh water, to decrease (or eliminate) water discharge, to decrease (or eliminate) solid waste discharge, and to make paper with increasing levels of post-consumer fibres (read: contaminated) and decreasing levels of virgin fibre (read: trees/plants).

The trends of lightweighting and increased post-consumer fibres are compounding the challenges in meeting paper strength requirements.

The trends of water & waste reduction and increased post-consumer contaminated fibres are compounding the challenges in meeting the safety needs of food contact paper products. This trend leads to higher system conductivities which is leading to increased levels of specialty chemicals required, which is antithetical to the desire to decrease papermaking costs.

With all these competing requirements the papermaker feels as though there are fewer tools available in order to make the final product; on time, on spec (read: meeting quality specifications), and on budget.

Residence time

Figure 1 shows that the water needed to make paper has not decreased, in fact the wet end of a paper machine remains at about 99% water. Figure 1 also shows that the effluent from paper machines has decreased over time. A consequence of using the same amount of water to make paper while decreasing the amount of water discharged as effluent has led to increased water re-use within the paper machine (read: paper mill).

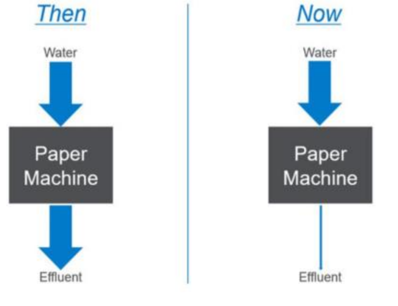

***Figure 1.** Decreased water discharge has led to increased re-use of water within the paper machine.*

If the volume of a system remains constant and the flow out of that system decreases, then residence time increases. Figure 2 shows us that if storage volume (V) of a paper machine remains constant and the volumetric flow (v) out of the paper machine decreases then the residence time (τ) of a system increases.

Increased residence time leads to anaerobic conditions (Robertson &Schwingel 1996), whereas decreased residence time leads to aerobic conditions (conditions favouring bacteria that thrive in the presence of oxygen). The relationship between volumetric flow and anaerobic/aerobic conditions is one that is often used in the study of swamps (Fitzgeraldet

***Figure 2.** Residence time of a vessel equals its volume over its discharge flow*

al 2003), where it has been found that higher rainwaterinputs prevent swamps from becoming completely anaerobic. For the papermaker this helps to confirm that increased freshwater flow through the process increases the oxygen content in water favouring aerobic metabolism rather than fermentation and anaerobic respiration that results in the formation of odour compounds including VFAs and hydrogen sulphide.

Physico-chemical and electrochemical parameters

From the laws of thermodynamics, we get temperature and Gibbs energy (Gibbs 1873). From Gibbs energy we get the Nernst equation (Nernst 1888). From the Nernst equation we get reductive oxidative potential (Eh, ORP, redox) and we also get pH (Sörensen 1909). From ORP and pH we get rH (Clark 1923) and the Pourbaix diagrams (Pourbaix 1966).

These physico-chemical and electrochemical parameters allow papermakers to study their stock systems in the same way that scientists study bovine digestive systems (Michellandet al 2011). This physico-chemical and electrochemical study allows for the determination of VFA production, which can lead to malodorous paper (Robertson & Rice 2006), and what bacteria are favoured by a system is in terms of anaerobic versus aerobic. Guided by these physico-chemical and electrochemical relationships we can choose the best parameters for any given system as to minimise the need for specialty chemicals. Maintaining higher pH, lower temperatures, and higher ORP will aid in preventing fermentation and VFA production by bacteria under anaerobic conditions.

Calcium carbonate, conductivity, and strength

Groundcalciumcarbonate(GCC, CaCO3) is a mineral used in papermaking because it is; white in colour, less expensive (in many cases) than fibre, provides opacity, and is easy to dry. One of the downfalls of GCC is that it dissolves into carbon dioxide and free calcium ions under acidic conditions. At papermaking temperatures of approximately 46°C, GCC dissolves completely at approximately 6.5pH. At papermaking temperatures of approximately 46°C and with 6.8-7.2 pH most of the GCC remains as a solid and provides the benefits to papermaking as described above. At low pH the calcium ions increase conductivity and adhere to the fibre surface by means of ionic exchange. There is a reduction in fibre zeta potential due to the adherence of calcium to the fibres, this also leads to a decrease in fibre-fibre bonding and a decrease in the efficiency of cationic specialty chemicals who rely on the anionic sites of the fibre surface to function.

Conclusion

Decreased effluent flow increases the residence time of papermaking systems, which in turn makes the papermaking system more anaerobic. The increased use of post-consumer fibre (read: contaminated) feeds the anaerobic bacteria and make it difficult to keep the paper hygienic for food contact. Anaerobic bacteria produce volatile fatty acids (VFAs) which lead to malodourous paper and a decrease in pH measurements. Decreased pH leads to the dissolving of ground calcium carbonate, and the liberation of free calcium ions. Free calcium ions increase system conductivity and adhere to fibre surfaces by ion exchange. The calcium laden fibres lead to a reduction in strength due to decreased fibre-fibre bonding. The calcium on the surface of the fibres also decrease the effectiveness of cationic specialty chemicals.

All efforts must be taken to prevent the papermaking systems from becoming anaerobic. This is a great challenge in the face of current industry trends, which include: decreased cost desires, increased strength desires, the need for food safe paper, and the demands of a circular economy (increased recycling/re-use, as well as decreased fresh water and virgin fibre use). In order to prevent anaerobic conditions a combination of physico-chemical, engineering, and biological controls should be taken. Physico-chemical actions to prevent anaerobic conditions include; lower temperatures, higher pH, and higher ORP. Engineering actions to prevent anaerobic conditions include; lower system volumes, higher system flows, aeration, and improved agitation. Biological controls to prevent anaerobic conditions should focus primarily on the use of oxidants but may need to include some non-oxidising biocides and other proprietary additives.

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